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Preliminary Estimates of Harbor Porpoise Abundance and By-Catch

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ABSTRACT

Improved estimates of the abundance and by-catch of harbor porpoise in New England waters are presented based on systematic sighting surveys and observer coverage of fishing activities. The estimates are significantly more reliable than those previously available, and suggest that there are substantially more harbor porpoise in the region and that the by-catch is substantially greater than previously thought. The estimates suggest that the ratio of by-catch to the population size is at least in the range 1 to 5%, and probably greater.

Several areas of uncertainty in the present estimates are identified. These include limitations of the data presently available for by-catch rates and fishing effort, and the need for more detailed analyses of the abundance data. A plan for accomplishing these additional analyses is outlined. Preliminary estimates are presented here in anticipation of more definitive estimates to be developed later because these new results are significantly different than those being relied upon for management purposes.

INTRODUCTION

Previously published information on abundance and by-catch of harbor porpoise in the Gulf of Maine suggests that large numbers of animals are possibly being removed from a relatively small population (IWC 1990, Polacheck 1989). The then-available data were very limited, however, and the estimates of both abundance and by-catch levels have large uncertainty.

To address these limitations, two new data collection programs were implemented by the Northeast Fisheries Science Center (NEFSC) in recent years, one to estimate abundance and the other to estimate harbor porpoise by-catch rates in the sink gillnet fishery. Inspection and preliminary analyses of data from these two programs suggest that the by-catch of harbor porpoise in the U.S. sink gillnet fishery is substantially greater than estimated previously, and that the abundance of this species in the Gulf of Maine and Bay of Fundy is considerably greater than previously estimated. Because of the need to develop management plans to control the by-catch of harbor porpoise under the 1988 amendments to the Marine Mammal Protection Act, preliminary estimates of both these quantities are presented here.

The estimates have relatively large uncertainty due both to sampling variability and to possible sampling biases. The general magnitudes of the estimates, however, are unlikely to change as data are further analyzed; thus these estimates provide a useful basis for making management plans.

The further analyses planned will address the several sources of uncertainty described below. These analyses will involve interactions with other scientists both in exploring alternate approaches to measuring fishing activity and to interpreting the present and previously collected harbor porpoise sighting data. These analyses when finalized will be subject to scientific review through the Northeast Fisheries Science Center Stock Assessment Workshop process.

ABUNDANCE ESTIMATES

A series of experiments was initiated in 1987 to develop and test methods of conducting sighting surveys for estimating harbor porpoise abundance (see Polacheck, Smith, and Waring 1991, Waring, Cox and Smith ms). Based on these experiments and on methods developed within the Scientific Committee of the International Whaling Commission

(see reports of the Scientific Committee of the International Whaling Commission in recent years), a complete sighting survey was conducted in the summer of 1991 (Palka and Potter ms). During the 40 days allocated for this survey, 28 days had suitable visibility and sea state conditions. During these 28 days, 2110 nm of track were searched using two independent sighting teams searching simultaneously. One team was located on the top-most crow's nest, and the other on a mid-level crow's nest. The membership of each team was fixed throughout the survey, and the teams were not rotated between the two crow's nests. During suitable sighting conditions, the team located highest on the vessel reported 475 sightings, while the team located lower reported 375 sightings of harbor porpoise.[1] The mean estimated number of animals per school was 2.9 (CV[2] 2.5%, 95% CI[3] 2.7 to 3.0).

The difference in the numbers of sightings by the two teams is large, and may be due to different sighting efficiency among the members of the two teams or to difference in visibility between the two crow's nests. The proportions of sightings made by the two teams at increasing distance from the trackline (right angles to the direction of motion of the vessel) were similar, suggesting that the difference in the number of sightings made is due to differences in the fraction of the schools present that were detected by each team.

A preliminary review of the data suggests that of the 850 sightings, as many as 206 of the sighted schools were possibly observed by both teams simultaneously (*i.e.* duplicate sightings). Of these, 134 were almost certainly duplicates. The uncertainty about the other 72 (=206-134) possibly duplicate schools is due to the difficulty in determining if two sightings were the same school when those sightings were made at nearly the same time. Further analyses of these data are required to better restrict this range of uncertainty. It is unlikely, however, that the actual number of duplicate sightings is outside this range. Further, these rates of duplicate sightings are consistent with our previous experimental studies of harbor porpoise, and with recent results for North Atlantic minke whales by Norwegian researchers, as reported to the International Whaling Commission.

Combining the data from both sighting teams, and considering the two extremes in the numbers of duplicate schools, the 1991 survey data can be used to estimate of the total population size, correcting for the fraction of the schools missed overall by both teams, using the method of Butterworth and Borchers (1991). The estimate of abundance of harbor porpoise would be roughly 45,000 (CV 24%) if the actual number of duplicated sightings were the higher number, 206. If, on the other hand, the actual number of duplicate sightings were 134, then the estimate would be 66,000 (CV 24%). The estimate would change proportionately over this range of numbers of duplicate sightings. For example, if half of the 72 uncertain schools were duplicates, then the estimate of abundance would be midway between these two point estimates, or 56,000. These numbers are summarized along with corresponding confidence intervals in Table 1.

These estimates are preliminary in that further review of the data is needed to confirm several areas on uncertainty. As mentioned, the uncertainty in the number of schools that both teams sighted needs to be resolved. This is planned using graphical display of the data and judgments from several scientists experienced with line transect applications to bound the uncertainty. In addition, greater statistical precision may be obtained by stratification by sea state, and by using post-stratification techniques to define geographic areas that better correspond to

[1] All sightings made during the cruise were used except for those from one day when sighting conditions were judged in retrospect to have been unacceptable, and four sightings which were reported incompletely

[2] Coefficient of variation, ratio of standard error of the mean to the value of the mean, expressed as a percent

[3] Confidence interval

Table 1. Estimates of total harbor porpoise population size in the Gulf of Maine in August 1991, with asymmetric 95% CI computed by the methods of Buckland (1991), depending on the number of duplicate sightings between the two independent teams

Number of Duplicate Sightings	Point Estimate	95% Confidence Intervals	
		Lower Limit	Upper Limit
134	66,000	41,000	105,000
206	45,000	28,000	72,000

the actual density of animals. Further, density of animals in the nearshore areas was assumed to be the same as seen immediately offshore, based on additional sighting data collected by the New England Aquarium during the same time period (A. Read, personal communication); further analyses of those data are needed to confirm this assumption. Finally, previous survey data suggests that these animals avoid the research vessel, at least at close ranges. Data collected during portions of the 1991 survey using 25 power binoculars will be analyzed to determine the distance from the vessel at which harbor porpoise move away from the trackline.

In addition to the above factors that will affect the point estimates, the statistical precision estimates used in the above analyses are based on theoretical calculations and are likely biased downwards. Correcting for this would result in somewhat greater statistical uncertainty than indicated. For example, the estimate of the fraction of schools seen by both teams will have its own statistical uncertainty which will be added into the calculations. Further, a major contribution to the statistical uncertainty comes from variability of sighting rates among survey lines, and the present analysis likely underestimates this uncertainty. This effect is better measured using statistical resampling techniques rather than the simpler theoretical calculations used here.

The estimates of harbor porpoise abundance presented here are greater than any given previously for this region. This is due in part to the broader spatial coverage of the survey and in part to the improved sighting survey methodology used. Although there are several uncertainties in the above estimates that will require additional study, it is apparent that there are substantially more harbor porpoise in this region than previously thought.

BY-CATCH ESTIMATES

Beginning in 1989, scientific technicians were placed aboard commercial fishing vessels by the Manomet Bird Observatory under contract to NEFSC to make observations on the catch and on the by-catch or discard of fishes, seabirds, sea turtles, and marine mammals. This program has continued with increasing emphasis on the Gulf of Maine sink gillnet fishery, with coverage by season and area roughly proportional to the extent of fishing activity. Between June 1989 and May 1991, 289 fishing trips were observed during which 34 harbor porpoise were reported killed. The distribution of the by-catch among observed fishing trips is highly skewed, with 264 trips having no by-catch, 18 trips having one porpoise killed, 5 having 2 animals killed, and 2 trips having 3 animals killed.

The data on rates of harbor porpoise by-catch can be used to estimate total numbers of animals killed by multiplying the rates by the total amount of fishing activity. Fishing activity can be measured using data collected by technicians in each fishing port (port agents)

Table 2. Numbers of vessels reported in the MMEP and port agent databases in 1990, for vessels of greater than and less than 5 gross registered tons

Database	> 5 GRT[1]	< 5 GRT[1]	Total
Port agent	183	-[2]	-
MMEP	98	38	136
Port agent and MMEP[3]	72	-	-

[1] Size category determined by presence of Coast Guard vessel registration number, which is required of all vessels greater than 5 GRT
[2] Information on individual vessels of less than 5 GRT is not included in port agent database
[3] Number of individual vessels for which fishing activity is indicated in both databases

under the NEFSC Statistics Investigation, and using data reported by fishermen under the National Marine Fisheries Service's Marine Mammal Exemption Program (MMEP). The port agents record data on the amount of fishing activity and the landings of fish based on information collected by fish processors and dealers, and based on dock-side interviews. Data are reported on catches and fishing activity by individual vessels for those vessels of greater than 5 gross registered tons (GRT), but only on catches for those vessels of less than 5 GRT. Fishermen holding marine mammal by-catch permits return logbooks under the MMEP program reporting fishing activity and any marine mammal by-catch.

The MMEP data for 1990 includes reports from 186 vessels holding sink gillnet by-catch permits, of which 136 reported actually fishing using that gear (Table 2). Of the 136 vessels, 98 had Coast Guard vessel registration numbers and were likely larger than 5 GRT. In contrast, the port agent data included reports of fishing activity for 183 vessels which were larger than 5 GRT. This difference (183-98) suggests that the port agent data are the more complete in terms of numbers of larger vessels.

Among the 98 vessels in the MMEP data and the 183 vessels in the port agent data, however, only 72 vessels appeared to be in both data bases, based on their Coast Guard Registration numbers. Thus fishing activity for 26 (=98-72) vessels appears to be included in the MMEP database but not in the port agent database. Further, the 72 larger vessels that appear in both data sets can be compared in terms of the amount of fishing activity reported. Due to constraints in the MMEP data, however, such comparisons are difficult. Preliminary analyses suggest that the MMEP data may be more complete for the amount of fishing activity for those vessels reporting, but the data are not sufficient to draw a firm conclusion and the best measure of fishing effort at present is the port agent data (NEFSC 1991).

There is no information that would allow estimating the degree of under-reporting of smaller vessels (under 5 GRT) in the port agent data, but it is possible that the extent of this under-reporting could be greater than that for the larger vessels because the data collection system has historically focused on the latter. Further analyses are needed to determine the representativeness of the two data bases, and to compare them in greater detail to other data sets that would indicate fishing effort.

Mean by-catch rates from the Observer Program database and numbers of fishing trips for both large and small vessels in the port agent database are summarized in Table 3, by quarter of the year for 24 months of sampling currently available. There is insufficient data to allow stratifying by statistical

Table 3. Data from the GOM sink gillnet fishery in harbor porpoise by-catch and reported numbers of fishing trips from the port agent data, by quarter of the year from May 1989 to May 1991

Quarter of the Year	# Trips	# Trips Observed	# Trips With No By-Catch	# Harbor Porpoise Killed	Mean Kill Per Trip	Std Error of Mean	Percent of Trips Sampled
6/89-8/89	4098	14	14	0	0.00	-	0.3
9/89-11/89	4282	71	67	5	0.07	.037	1.7
12/89-2/90	1577	31	28	5	0.16	.094	2.0
3/90-5/90	2977	52	48	6	0.12	.065	1.7
6/90-8/90	5542	31	31	0	0.00	-	0.6
9/90-11/90	3863	35	29	7	0.20	.080	0.9
12/90-2/91	1608	17	13	4	0.24	.106	1.1
3/91-5/91	2178	38	34	7	0.18	.099	1.7
Total	**26125**	**289**	**264**	**34**	**0.12**	**.025**	**1.1**

area and season, but the sample coverage appears to have been more representative by area than by season. Strong seasonal changes in the numbers of fishing trips made and the mean number of harbor porpoise killed per trip are apparent, with highest numbers of trips and lowest by-catch rate seen in the summer months. The change in by-catch rate by season is due in part to seasonal changes in the distribution of harbor porpoise. The observed by-catch rates were higher in the second year than in the first for all three of the quarters in which animals were observed killed. Given the low sample sizes, however, the differences are not statistically significant and could have occurred by chance.

The by-catch estimated as the seasonally stratified product of the by-catch per fishing trip and the numbers of trips from the port agent data rounds to 2500 animals (CV 20%, 95% CI 1500 to 3500) for the two year period sampled. The corresponding value on an annual basis would be 1250 (CV 20%, 95% CI 750 to 1750).

There are several uncertainties about these estimates. First, as discussed earlier, are the possible limitations in the port agent data that may result in these estimates being biased downward. In addition, because of the low fraction of the fishing trips that were sampled, it is not feasible to stratify by area and hence better account for seasonal movements. However, alternate calculations where such stratification was attempted provided similar values to those given above. In addition, this estimate of by-catch levels is also subject to possible downward biases because some of the animals killed in nets have been seen to drop out of the gear as it is retrieved. It is likely that not all of those animals are detected. Because of safety considerations on smaller vessels and differential degrees of cooperativeness among fishermen, not all fishing trips are equally likely to be sampled. It is possible that the vessels which have carried observers have different kill rates (higher or lower) than those that have not. This could be due to different fishing practices (including different fine-scale spatial distribution of gear) among fishermen, or to changes in fishing practices by fishermen when they carry an observer. It may be possible to test for such effects by comparing the species composition and amount of the fish landings from observed and unobserved fishing trips and vessels.

The statistical precision of this estimate was computed using simple statistical sampling methods. Because the distribution of the numbers of harbor porpoise killed per

Table 4. Ratio of estimates of U.S. by-catch (1250 per year, CV 20%) to population size (45,000 to 66,000, CV 24%) for harbor porpoise in the Gulf of Maine and Bay of Fundy

Population Size	Ratio (%)	CV[1]	95% Confidence Interval[2]	
			Lower Limit	Upper Limit
45,000	2.8	31	1.6	5.1
66,000	1.9	31	1.1	3.4

[1] Using Taylor's series approximation
[2] Asymmetrical interval using method of Buckland (1991)

trip is skewed (high proportion of trips with no animals killed), statistical resampling procedures would likely provide more robust and higher estimates of statistical uncertainty.

Although there are large uncertainties in the estimate of the total U.S. sink gillnet by-catch given, it is apparent that the number of animals killed annually is likely to be substantially greater than suggested by the International Whaling Commission (1990) and Polacheck (1989). Based on previously available data from several studies and reports, Polacheck suggested, for example, by-catches of 600 by U.S. sink gillnet fishermen and 130 by Canadian gillnet fishermen. The lower confidence limit on the U.S. by-catch estimate (750) exceeds that level and, considering that the estimates presented here may be biased downward, it appears that more animals are being killed than previously thought.

RATIO OF BY-CATCH TO ABUNDANCE

The ratio of the by-catch to the total population size as a percent is a simple indication of the potential impact of mortality due to fishing. Values larger than a few percent would suggest that the by-catch may not be sustainable over several years. Using the two estimates of abundance of 45,000 and 66,000, and the annual estimate of by-catch of 1250, estimates of this ratio with nominal 95% confidence intervals are shown in Table 4. Depending on assumptions, the estimates range between 1.1 and 5.1% per annum. Because estimates of by-catch may be biased downward, these ratio estimates may be biased downward. This implies that the actual by-catch is almost certainly greater than 1% of the population, and could be substantially greater.

This analysis relates to the effect of the by-catch due to U.S. sink gillnet vessels. The effect of Canadian sink gillnet fishing activity, and of other human-induced mortality, needs to be considered also. Further study is required to improve the estimates of abundance and by-catch mortality presented here, and information is needed on the degree of population separation in this region (if any), vital rates, and age/sex composition of the by-catch, to allow better determination of the actual significance of different percentage rates of by-catch.

CONCLUSION

The four data sets used to prepare the preliminary estimates of by-catch and abundance need to be analyzed further before definitive estimates can be developed. These further analyses must address several sources of uncertainty within each of the databases, as identified earlier, as well as uncertainties in the analytic methods used. Although the

crude ratio of by-catch to abundance provides an indication that the level of by-catch is serious but not catastrophic, analyses of the effect of by-catch that directly account for the age composition of the by-catch and the natural reproductive capability of harbor porpoise are needed. The following steps are recommended to finalize the estimates of by-catch and abundance, and to evaluate better the biological significance of by-catch:

1. Further analyses of sightings data, including developing robust methods for determining the numbers of duplicated sightings between the two sighting teams, and direct incorporation of sightings data collected in inshore areas.

2. Further analyses of observer data on by-catch, including information collected since June 1991 when the higher percentage coverage was begun.

3. Further analyses of the data on fishing effort, including those reported by the fishermen under the Marine Mammal Exemption Program and those collected by NEFSC port agents, both for recent years and for earlier years.

4. Biological analyses of the carcasses and tissue samples from the animals killed in the fishery, including evaluation of the earlier results from studies of harbor porpoise sampled from the Canadian fishery, especially on vital rates and stock structure.

Results from these four lines of study will become available in the first half of 1992, and should be evaluated in a scientific workshop which would review revised estimates of abundance and by-catch levels, evaluate information on the biological effect of the by-catch, and advise on steps which should be taken for further research.

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